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"GLOBAL MAGNETOHYDRODYNAMIC MODELING OF THE SOLAR CORONA"

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2nd Quarter (3rd Year) Progress Report,

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GLOBAL MAGNETOHYDRODYNAMIC MODELING OF THE SOLAR CORONA

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Coronal mass ejections (CMEs) are believed to be the primary cause of non-recurrent geomagnetic storms. Central to the geoeffectiveness of CMEs is the topology of the magnetic field structures contained within the CME, as southward pointing magnetic fields (magnetic fields that are antiparallel to the ambient Earth field at the Earth's magnetopause) are crucial to the production of geomagnetic activity.

The connection between the origin of CMEs in the corona and their interplanetary properties is still poorly understood. We have investigated the evolution of CMEs initiated by magnetic flux cancellation in three-dimensional MHD simulations. Previously, we (Amari et al. 2000; Linker et al. 2001) have found that have found that reduction of the magnetic flux near the neutral line (flux cancellation) can lead to the formation of magnetic flux ropes in sheared or twisted arcade configurations. When the flux reduction reaches a critical threshold, the entire configuration erupts with a considerable release of magnetic energy. In two spatial dimensions (azimuthal symmetry imposed in spherical coordinates) the flux rope forms a torus around the sun, which is clearly not realistic. Two-dimensional calculations can be useful for elucidating some of the basic physical processes, but clearly cannot be used to understand details of the magnetic topology of CMEs.

The top panels of Figure 1 shows a time sequence of the magnetic field evolution for eruption of a simulated CME in a three-dimensional calculation. The bottom panels show the same field line evolution together with isosurfaces (gold) of the scaled plasma density. The sphere depicted in each frame shows the position of the Sun; as time advances the viewpoint for each frame recedes so that a larger region of the computational domain is shown. In (a) and (b), the streamer belt on the right side of the Sun is erupting; the higher density associated with the embedded flux rope can be seen. On the left side of the Sun, the stable portion of the streamer remains relatively unchanged. In (b) and (c), the twisted flux rope field lines can be seen to be associated with the enhanced plasma density that propagates outward.

Evolution of a 3D CME Eruption: Density Surface + Magnetic Field Lines

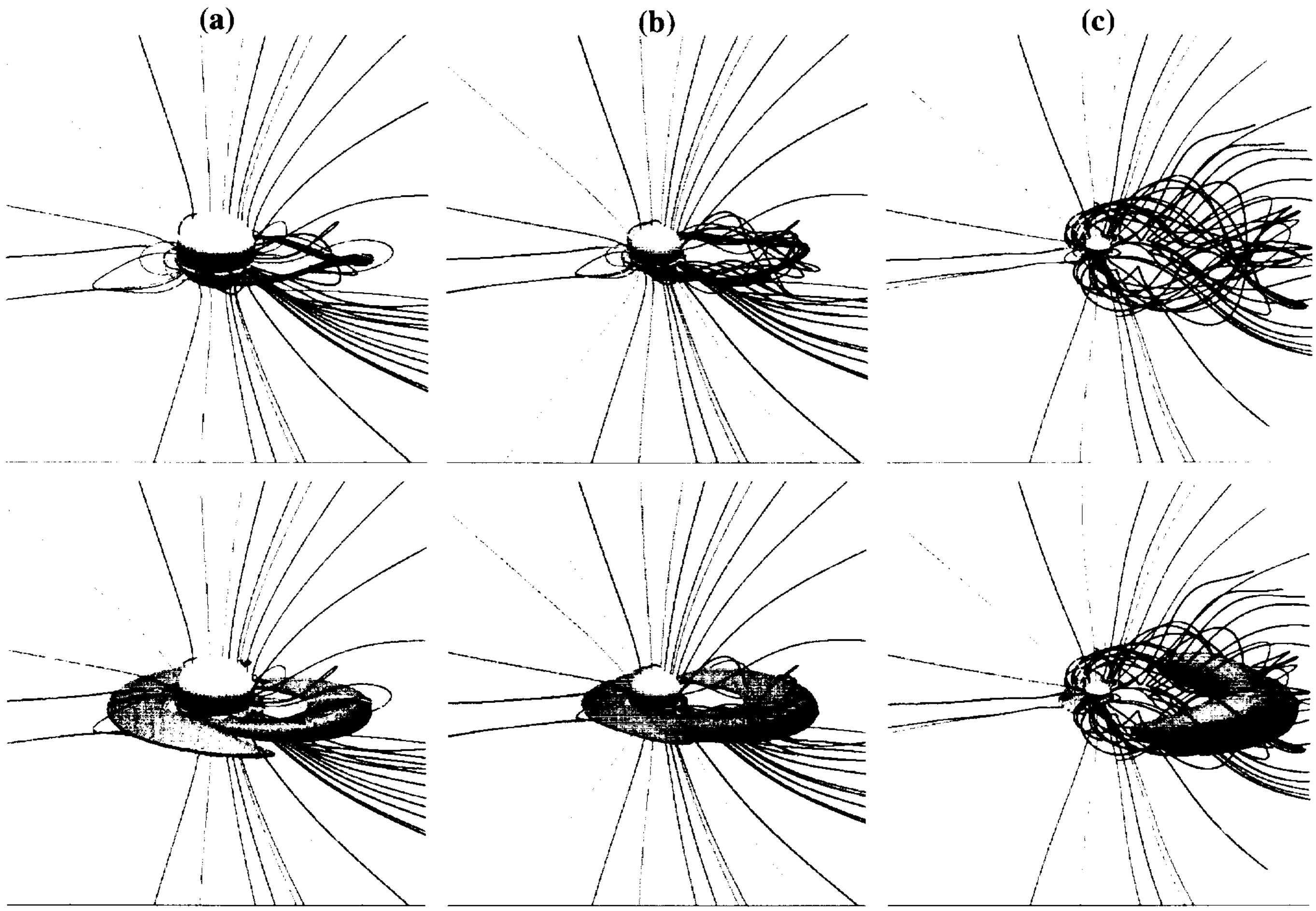

Figure 1. Magnetic field evolution in a simulated 3D CME. The top panels show the magnetic field evolution. The bottom panels show the same field lines together with isosurfaces of the scaled plasma density. **(a)** The helmet streamer configuration has erupted; the undisturbed portion of the streamer can be seen in surface on the left while the bright core of the CME can be seen on the right. **(b)** The same eruption two hours after (a). **(c)** The same eruption 7 hours after (a).

Figure 2 shows views of the different magnetic field topologies exhibited by the simulated ejection. Unlike the 2D case, the helical field lines associated with the CME remain anchored to the Sun. A spacecraft intersecting this structure would not only measure field signatures associated with magnetic clouds, but would also observe a signature of bi-directional heat flux which often accompanies CMEs (Gosling et al. 1987). One can also see other topological features associated with the eruption; for example, the U-shaped field lines behind the magnetic cloud, which may be associated with heat flux dropouts (McComas et al. 1989).

3D CME Eruption: Magnetic Field Topology

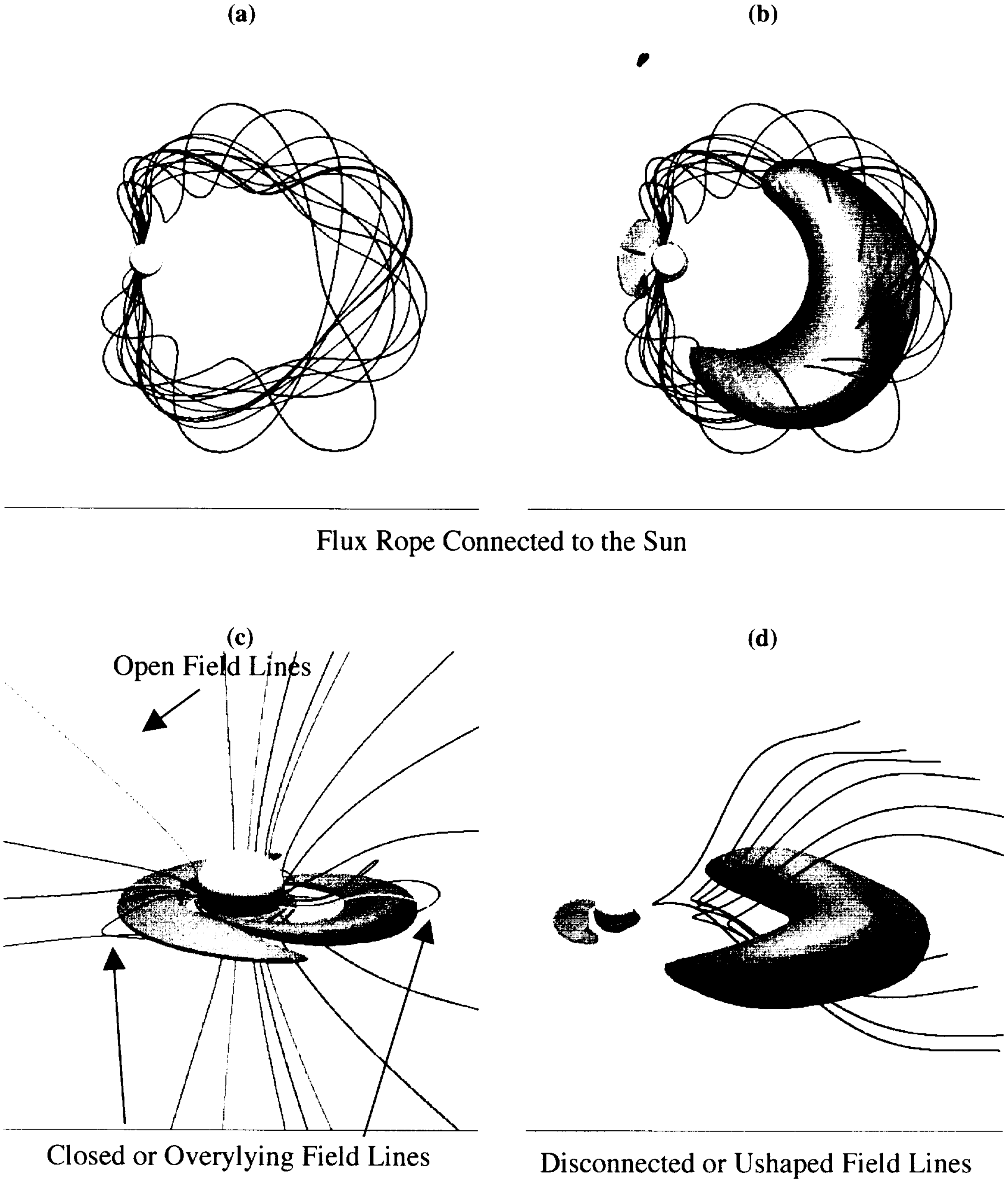

Figure 2. Topological features of the magnetic field for the simulated 3D CME shown in Figure 1. Magnetic fields lines are shown together with isosurfaces of the scaled plasma density. **(a)** and **(b)** show a view of the CME from above the north pole of the Sun. Helical field lines anchored to the Sun at both ends are associated with the magnetic cloud structure. **(c)** Closed, unsheared field lines overlay the erupting structure; these loops are carried out into the solar wind as part of the CME. **(d)** Disconnected field lines are present behind the flux rope.

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In this report we describe progress in our investigation of the solar corona using magnetohydrodynamic (MHD) simulations.

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